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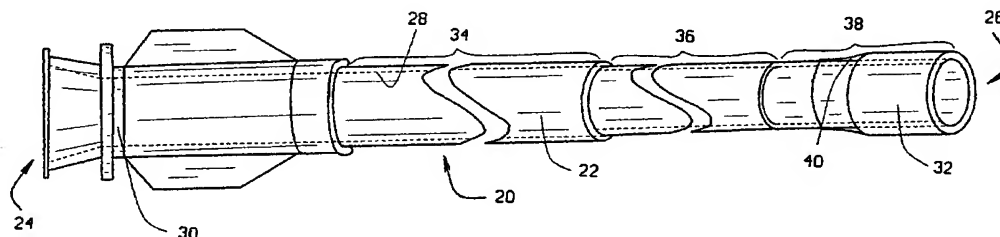
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(54) Title: VARIABLE STIFFNESS MAGNETIC CATHETER



(57) Abstract: A steerable magnetic catheter (20) having a proximal end (24), a distal end (26), and a lumen (28) therebetween. The catheter (20) has regions (34, 36, 38) of different flexibility along its length. There is a magnetic body (32) adjacent the distal end (26), which is responsive to an applied magnetic field. The magnetic body (32) is sized and the flexibility of the distal end portion (26) of the catheter (20) is selected so that the distal end (26) of the catheter (20) can be manipulated with a magnetic field of a practical strength, eliminating the need for a guidewire.

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## VARIABLE STIFFNESS MAGNETIC CATHETER

### FIELD OF THE INVENTION

This invention relates to catheters, and in particular to variable stiffness  
5 magnetic catheters.

### BACKGROUND OF THE INVENTION

Magnetic catheters are catheters provided with a magnetic member by which  
the distal end of the catheter can be navigated (oriented and/or moved) by the  
10 application of a magnetic field. There are competing considerations in the  
construction of these catheters. The distal end must be sufficiently flexible to readily  
orient in response to the force applied by the magnetic field on the magnetic member  
while the lumen of the distal end must be sufficiently strong to resist kinking.  
However, the entire catheter must be sufficiently stiff to enable advancement through  
15 the patient's body.

### SUMMARY OF THE INVENTION

The present invention comprises a steerable magnetic catheter in which the  
flexibility varies along its length, and which preferably can be navigated without a  
20 guidewire. Generally, the catheter has a proximal end and a distal end, and a lumen  
extending therebetween. The catheter has regions of different flexibility along its  
length. There is a body, responsive to an applied magnetic field, and/or gradient,  
adjacent the distal end. The magnetic field and/or gradient may be applied with at  
least one stationary or at least one moveable magnet.

25 The body may be a permeable magnetic material, such as cold rolled steel or a  
permanent magnetic material such as neodymium-iron boron.

The distal end of the catheter is sufficiently flexible and the body is sized such  
that the catheter can bend at least 45° in response to an applied field of 0.25T or less  
and more preferably at least 60° , and most preferably 90° within about 5 mm of the  
30 magnetic member, which is typically at the distal end of the catheter. This allows  
navigation in small (less than 5 mm in diameter) vessels. The distal end is more  
preferably responsive to an applied magnetic field of 0.2T or less, and most preferably  
to an applied magnetic field of 0.1T or less.

As described above the catheter has at least two, and preferably at least three, regions of different flexibility. Each region is preferably of successively greater flexibility from the proximal end to the distal end.

5

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of a variable stiffness magnetic catheter constructed according to the principles of this invention;

10 Fig. 2 is a perspective view of a first alternate construction of the distal end of the catheter;

Fig. 3 is a perspective view of a second alternate construction of the distal end of the catheter;

Fig. 4 is a perspective view of a third alternate construction of the distal end of the catheter;

15 Fig. 5 is a longitudinal cross-sectional view of a second embodiment of a catheter constructed according to the principles of this invention;

Fig. 6 is a longitudinal cross-sectional view of a third embodiment of a catheter constructed according to the principles of this invention.

20 Fig. 7 is a longitudinal cross-sectional view of a fourth embodiment of a catheter constructed according to the principles of this invention; and

Fig. 8 is a longitudinal cross-sectional view of a fifth embodiment of a catheter constructed according to the principles of this invention.

Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

25

## DETAILED DESCRIPTION OF THE INVENTION

A first embodiment of a steerable, variable stiffness magnetic catheter constructed according to the principles of this invention is indicated generally as 20 in Fig. 1. The catheter 20 is a tube 22 having a proximal end 24 and a distal end 26. A lumen 28 extends substantially from the proximal end 24 to the distal end 26.

30

A conventional luer connector 30 is mounted on the proximal end 24 of the tube 22. A body 32 is mounted on the distal end of the tube 22. The body 32 includes a magnetically responsive material, for example a permeable magnetic material such as cold rolled steel, an iron-cobalt alloy (e.g. 50% iron 50% cobalt) or Hyperco™ or a

permanent magnetic material such as neodymium-iron-boron. The body 32 is made of a material, and is of such dimensions, that under the influence of an applied magnetic field, the distal end portion of the catheter aligns with the local applied magnetic field direction. The body may have the form of a solid body, a tube, or a coil.

5           The tube 22 has regions of different flexibility. In the preferred embodiment shown in Fig. 1, there are three regions 34, 36 and 38. Region 34 has an internal diameter of about 0.021 inches, an outer diameter of about 0.034 inches, and a length of between about 100 cm and about 140 cm. Region 34 is kink-resistant and axially stiff for advancement of the catheter.

10           Region 36 has an internal diameter of about 0.021 inches, an outer diameter of about 0.034 inches, and a length of between about 10 cm and about 30 cm. The region 36 preferably has a greater flexibility than region 34. Region 36 is kink-resistant and flexible to allow passage through small vessel branches (i.e., branches less than about 5 mm).

15           Region 38 has an internal diameter of about 0.021 inches, an outer diameter of about 0.034 inches, and a length of between about 0.5 cm and about 5 cm. The region 38 preferably has a greater flexibility than regions 34 and 36. Region 38 is kink-resistant and extremely flexible to allow magnetic control within small vessel branches (i.e., branches less than about 5 mm).

20           In the case where catheter 20 is specifically adapted for a neurovascular procedure, the length of the region 34 is selected to extend generally from the patient's femoral artery to the carotid artery; the length of the region 36 is sufficient to pass through the neurovasculature; and the length of the region 38 is sufficient to allow the distal end of the device to align with an applied magnetic field.

25           Thus the tube flexibility increases from the proximal end to the distal end. The flexibility of each region is preferably constant, but the flexibility of each region could vary along its length so that the increase in flexibility along the length of the catheter is more continuous, with less abrupt changes between adjacent regions.

          The body 32 is generally tubular, with an inner diameter of between about  
30   0.022 inches and about 0.026 inches, and an outer diameter of between about 0.033 inches and about 0.038 inches. The body preferably has a volume of about 0.4 mm<sup>3</sup> to about 0.8 mm<sup>3</sup> and a length of between about 1 and about 3 mm. The magnet is sized to be as small as possible, while still providing sufficient torque when a magnetic field is applied to steer the catheter. The body 32 is secured over the region 38 of the

tube 22, adjacent the distal end 26, with an adhesive layer or polymer coating 40, which also provides a smooth transition between the body 32 and the external surface of tube 22. The distal-most portion of region 38 has a reduced outside diameter to accommodate the body 32. In this preferred embodiment the outside diameter of the distal region is about 0.023 inches.

A first alternate construction of the distal end is shown in Fig. 2. A generally tubular body 32' is mounted inside the distal end of the tube 22. The body 32' has an inner diameter of about 0.022 inches, and an outer diameter of about 0.032 inches. The body 32' has a length of about 2 mm. The body 32' is frictionally secured inside the lumen 28, and may also be secured with an adhesive layer or polymer coating.

A second alternate construction of the distal end is shown in Fig. 3. A generally tubular body 32" is mounted on the outside of the distal end of the tube 22. The body 32" has an inner diameter of about 0.028 inches, and an outer diameter of about 0.038 inches. The body has a length of about 2 mm. The body 32" can be secured over the region 38 of the tube 22, adjacent the distal end 26, with an adhesive layer or polymer coating 42, which also provides a smooth transition between the body 32" and the external surface of the tube 22. The second alternative construction differs from the primary embodiment in that this second alternate construction the distal most portion of section 38 does not have a reduced outside diameter to accommodate the body 32".

A third alternate construction of the distal end is shown in Fig. 4. A body 32''' is mounted on the distal end of the tube 22 with a collar 44, a portion of which fits inside the lumen 28 of the tube, and a portion of which fits inside the bore of the body 32''' The collar 44 has an inner diameter of about 0.021 inches, an outer diameter of about 0.022 inches, and a length of about 2.5 mm. The body 32''' has an inner diameter of about 0.023 inches, an outer diameter of about 0.034 inches, and a length of about 1.7 mm. The body 32''' can be secured on the end of the tube 22 with a highly flexible sheath or polymer coating 46 extending over the distal end of the tube and over the body 32'''. The sheath is approximately about 2 mm to about 20 mm long.

Preferably each of the regions 34, 36 and 38 is of successively greater flexibility from the proximal end to the distal end, such that the more distal the region, the more flexible it is. This ensures that the proximal end is sufficiently stiff that the catheter can be advanced by pushing, yet the distal end is sufficiently flexible that

applied magnetic field can apply sufficient force to orient and/or move the body. However, a region can be provided with increased stiffness relative to the next most proximal section, for example to improve the ability to advance the catheter.

5 The body 32 (or 32', 32", or 32''') could comprise a plurality of separate members spaced along the distal end portion of the catheter 20. This allows the shape of the distal end portion to be controlled by the application of an appropriately shaped magnetic field.

10 The relative length and flexibility of the regions 34, 36 and 38 can be selected to facilitate a particular procedure. For example, the flexible catheter 20 of the preferred embodiment is particularly adapted for interventional neuroradiology procedures, e.g. aneurysm or AVM treatment. The distal-most region 38 is highly flexible and is between about 0.5 cm and about 5 cm long, which is sufficiently long for catheter positioning within vascular defects such as aneurysms. The proximal adjacent region 36 is less flexible and is between about 10 cm and about 30 cm long  
15 which is sufficiently long to traverse small vessels within the neurovasculature. Of course different lengths and different flexibilities can be selected to facilitate navigation in other parts of the body.

The outside diameter of the distal end portion of the catheter is preferably less than about 0.038 inches, and more preferably less than about 0.034 inches, so that the  
20 distal end of the catheter can fit within small blood vessels, such as those in the brain or at the heart. The inner diameter of the catheter is preferably at least about 0.021 inches, and is smooth and continuous so that objects, such as coils for embolizing aneurysms can be delivered through the lumen.

It is desirable that at least the distal section 38 be flexible enough to permit the  
25 distal end to be freely navigated with relatively small applied magnetic fields. It is preferred that at a minimum the catheter can flex at least about 45° under an applied magnetic field of about 0.25T or less, within about 5 mm of the body 32, and more preferably that the catheter can bend at least about 60° , and most preferably at least about 90° with this applied magnetic field. It is of course, even more desirable that  
30 the catheter can flex at least about 45° under an applied magnetic field of about 0.2T or less, within about 5 mm of the body, and more preferably at least about 60° , and most preferably at least about 90° . It is most desirable if the catheter can bend at least about 60° under an applied magnet field of about 0.1T or less, within about 5 mm

of the body 32, and more preferably that the catheter can bend at least about 60°, and most preferably at least about 90° with this applied magnetic field in this span.

The ability to turn within a 5 mm length of the body has been found sufficient to successfully navigate the neurovasculature and other small vessels between about 1 mm and 5 mm in diameter. Practical magnet systems can generate magnetic fields of up to about 0.25T to about 0.3T in an operating region in a patient. It is preferable to use even lower fields of 0.2T, and preferably as low as 0.1T, to reduce the time required to change the magnetic field direction and thus speed navigation. A 45° bend in the catheter tip is generally sufficient to make 90° turns, and turning is further improved if the catheter can bend at least 60°, and more preferably at least 90°.

While it is desirable that the catheter, and particularly the distal regions of the catheter, be highly flexible, it is important that the catheter not "kink" or bend so sharply that the lumen decreases in size such that it is no longer functional. In general it is desirable that the lumen 28 remain open to the extent that an 0.018 inch diameter coil can pass through the lumen. As described below, coils or braiding can be incorporated into the wall of the catheter to allow flexing while resisting kinking.

The steerable variable stiffness magnetic catheter can be made sufficiently flexible to be flow-directed into blood vessels. Under flow-direction the catheter is sufficiently flexible that the distal end of the catheter will generally follow the branch with the greatest flow. When it is desired to navigate the catheter to a branch other than the branch with the greatest flow, a magnetic field or gradient can be applied to the magnet body 32 on distal end of the catheter 20 to orient and/or move the distal end of the catheter. Thus, the catheter 32 can be used as a magnetically navigable flow-directed catheter.

The distal end of a second embodiment of a steerable variable stiffness magnetic catheter constructed according to the principles of this invention, indicated generally as 100, is shown in a longitudinal cross section in Fig. 5. The catheter 100 comprises at least two sections of different flexibility, and may be constructed similar to catheter 20 of the first embodiment.

The catheter 100 has a proximal end (not shown) and a distal end 104, and has a sidewall 106 with a lumen 108 therein extending substantially from the proximal end to the distal end 104. The catheter 100 has a magnet body 110 in its distal end 104. The magnet body 110 may be a permeable magnetic material, such as cold rolled steel, or a permanent magnetic material, such as neodymium-iron boron. Because the

magnet body 110 is solid, it has greater mass than the hollow magnet body 32 of the first embodiment, and thus can apply a greater torque to catheter 100 for a given applied magnetic field/gradient than can body 32 on catheter 20.

There is preferably at least one opening 112 in the sidewall 106 of the catheter 100. The size, position and number of openings depends upon the particular application.

Where, for example, the catheter is to be used to deliver coils to embolize an aneurysm, there would be only one opening (to control the placement of the coils), large enough to allow the coils to pass through it. The magnetic moment of the magnetic body could be used to align the side opening, i.e. the magnetic moment can be oriented other than in the axial direction, which would allow the distal end of the catheter to be turned about the axis to align the opening in the sidewall in a particular direction. Where, for example, the catheter is to be used for deploying an elongate medical device, there would also be only one opening through which the device can be deployed. Where, for example, the catheter is used to deliver a medical substance such as a therapeutic agent or a diagnostic agent, there might be a plurality of small openings positioned and arranged around the circumference of the sidewall 106 to deliver the therapeutic or diagnostic agent.

A curved ramp 114 can be provided in the distal end of the lumen 108 to facilitate dispensing coils through the opening 112 and to facilitate deploying medical devices.

The distal end of a third embodiment of a steerable variable stiffness magnetic catheter constructed according to the principles of this invention, indicated generally 200, is shown in the longitudinal cross section in Fig. 6. The catheter 200 comprises at least two sections of different flexibility, and may be constructed similar to catheter 20. In this preferred embodiment there are three sections, proximal section 202, a more flexible intermediate section 204, and a highly flexible distal section 206.

The catheter 200 has a proximal end (not shown) a distal end 208 with a sidewall 210 with a lumen 212 extending substantially from the proximal end to the distal end 208. There is a tubular magnet 218 embedded in the distal end of the distal section 206, with the bore of the tube aligned with the lumen 212. A wire coil 214 is embedded in the sidewall 210 of the section 206. The coil 214 helps the distal section 206 resist kinking, while leaving the distal section 206 highly flexible. Wire braiding



216 is embedded in the sidewall 210 of the proximal and intermediate sections 202 and 204. The braiding 216 helps stiffen the intermediate and proximal sections 202 and 204 and resist kinking. This construction also helps minimize "ovaling" (i.e., reduction of the cross sectional dimensions) of the inner catheter lumen.

5           The distal end of a fourth embodiment of a steerable variable stiffness magnetic catheter constructed according to the principles of this invention, indicated generally 300, is shown in the longitudinal cross section in Fig. 7. The catheter 300 comprises at least two sections of different flexibility, and may be constructed similar to catheter 20. In this preferred embodiment there are three sections, proximal section  
10   302, a more flexible intermediate section 304, and a highly flexible distal section 306. No braiding is employed in this embodiment. Instead, the polymers chosen for the tubing extrusion, separately or in combination, provide the axial and radial support of the catheter, as well as kink resistance, while leaving the distal segment highly flexible.

15           The catheter 300 has a proximal end (not shown) a distal end 308 with a sidewall 310 with a lumen 312 extending substantially from the proximal end to the distal end 308. There is a tubular magnet 318 embedded in the distal end of the distal section 306, with the bore of the tube aligned with the lumen 312. This construction also helps minimize "ovaling" (i.e., reduction of the cross sectional dimensions) of the  
20   inner catheter lumen.

          The distal end of a fifth embodiment of a steerable variable stiffness magnetic catheter constructed according to the principles of this invention, indicated generally 400, is shown in the longitudinal cross section in Fig. 8. The catheter 400 comprises at least two sections of different flexibility, and may be constructed similar to catheter  
25   20. In this preferred embodiment there are three sections, proximal section 402, a more flexible intermediate section 404, and a highly flexible distal section 406.

          The catheter 400 has a proximal end (not shown) a distal end 408 with a sidewall 410 with a lumen 412 extending substantially from the proximal end to the distal end 408. A wire coil 414 made from a paramagnetic material such as Hyperco,  
30   is embedded in the sidewall 410 of the section 406. Tightly wound (i.e. tight pitch), the distal coil 414 helps the distal section 406 resist kinking, while leaving the distal section 406 highly flexible. When the distal coil is of a more open design (i.e. open pitch), the distal tip 406 becomes magnetically steerable. The magnetic moment of the para-magnetic body could be used to align the side opening, i.e. the magnetic moment

can be oriented other than in the axial direction when the coiling pitch is “open”, which would allow the distal end of the catheter to be turned about the axis to align the opening in the sidewall in a particular direction. Where, for example, the catheter is to be used for deploying an elongate medical device, there would also be only one opening through which the device can be deployed. Where, for example, the catheter is used to deliver a medical substance such as a therapeutic agent or a diagnostic agent, there might be a plurality of small openings positioned and arranged around the circumference of the sidewall 106 to deliver the therapeutic or diagnostic agent. A non-paramagnetic wire braiding 416 is embedded in the sidewall 410 of the proximal and intermediate sections 402 and 404. The braiding 416 helps stiffen the intermediate and proximal sections 402 and 404 and resist kinking. This construction also helps minimize "ovaling" (i.e., reduction of the cross sectional dimensions) of the inner catheter lumen.

A localization component could be included in the distal end of the catheter, preferably adjacent the magnetic body, to enable non-fluoroscopic localization of the catheter. Such a component might be a magnetic, ultrasonic, or rf localization device. This is particularly useful with side exit catheter

What is claimed is:

1. A steerable catheter having a proximal end and a distal end and a lumen extending therebetween, regions of different flexibility along its length, and at least one body adjacent the distal end responsive to an applied magnetic field.
2. The catheter according to claim 1 wherein at least one body includes a permeable magnetic material.
3. The catheter of claim 2 where the permeable material is steel.
4. The catheter of claim 2 where the permeable material is about 50% iron and 50% cobalt.
5. The catheter of claim 2 where the magnet body is in the form of a coil.
6. The catheter of claim 5 where the coil is embedded in the wall of the catheter.
7. The catheter of claim 6 in which the coil supplies both structural support to the catheter and magnetic deflection.
8. The catheter according to claim 1 wherein at least one body includes a permanent magnetic material.
9. The catheter according to claim 8 wherein at least one body includes a neodymium iron boron magnetic material.
10. The catheter according to claim 1 wherein the catheter has at least one generally axial opening at its distal end communicating with the lumen, through the body.
11. The catheter according to claim 1 wherein the catheter has at least one lateral opening therein, and wherein the body is distal to the lateral openings.
12. The catheter according to claim 1 wherein the catheter is adapted for use in interventional neuroradiological procedures.
13. The catheter according to claim 1 wherein the catheter is adapted for use in navigation in the blood vessels of the heart.
14. A catheter having a proximal end and a distal end and a lumen extending therebetween, regions of different flexibility along its length, and a body adjacent the distal end responsive to an applied magnetic field of about 0.25 T or less to bend the catheter up to at least about 45° within 5 mm of the body.

15. The catheter according to claim 14 wherein the body adjacent the distal end is responsive to an applied magnetic field of 0.25 T or less to bend the catheter up to at least about 60° within 5 mm of the body.

16. The catheter according to claim 14 wherein the body adjacent the distal end is responsive to an applied magnetic field of 0.25 T or less to bend the catheter up to at least about 90° within 5 mm of the body.

17. A catheter having a proximal end and a distal end and a lumen extending therebetween, regions of different flexibility along its length, and a body adjacent the distal end responsive to an applied magnetic field of 0.20 T or less to bend the catheter up to at least about 45° within 5 mm of the body.

18. The catheter according to claim 17 wherein the body adjacent the distal end is responsive to an applied magnetic field of 0.20 T or less to bend the catheter up to at least about 60° within 5 mm of the body.

19. The catheter according to claim 17 wherein the body adjacent the distal end is responsive to an applied magnetic field of 0.20 T or less to bend the catheter up to at least about 90° within 5 mm of the body.

20. A catheter having a proximal end and a distal end and a lumen extending therebetween, regions of different flexibility along its length, and a body adjacent the distal end responsive to an applied magnetic field of 0.1 T or less to bend the catheter up to at least about 45° within 5 mm of the body.

21. The catheter according to claim 20 wherein the body adjacent the distal end is responsive to an applied magnetic field of 0.1 T or less to bend the catheter up to at least about 60° within 5 mm of the body.

22. The catheter according to claim 21 wherein the body adjacent the distal end is responsive to an applied magnetic field of 0.1 T or less to bend the catheter up to at least about 90° within 5 mm of the body.

23. A catheter having a proximal end and a distal end and a lumen extending therebetween, regions of different flexibility along its length, and a body, adjacent the distal end, the distal end region being sufficiently flexible to be responsive to an applied magnetic field of 0.2 T or less to bend up to about 90° within 5 mm of the body to substantially align the distal end portion of the catheter with the field direction.

24. A magnetically navigable catheter having a proximal end and a distal end, the catheter having sections of different flexibility, the distal most section being

highly flexible and having a body thereon responsive to an applied magnetic field sufficient to align the distal end of the catheter with the applied magnetic field.

25. The magnetically navigable catheter according to claim 24 wherein the body has a volume of about 0.6 mm<sup>3</sup>.

26. The magnetically navigable catheter according to claim 24 wherein the body has a length of about 2mm.

27. The magnetically navigable catheter according to claim 24 wherein the body has an aspect ratio of about 2:1.

28. The magnetically navigable catheter according to claim 24 wherein the catheter has at least three sections of different flexibility.

29. The magnetically navigable catheter according to claim 23 wherein each section is more flexible than the adjacent proximal section.

30. The magnetically navigable catheter according to claim 29 wherein the distal-most section has a length of between about 0.5 cm and about 5 cm.

31. The magnetically navigable catheter according to claim 25 wherein the section proximal to the distal-most section is between about 10 cm and about 30 cm.

32. The magnetically navigable catheter according to claim 24 wherein the outside diameter of the distal most section is less than about 0.038 inches.

33. The magnetically navigable catheter according to claim 24 wherein the distal most section can bend about 90° over a length of 5 mm without kinking.

34. The magnetically navigable catheter according to claim 24 wherein the body has a bore therethrough, and is secured over the exterior of the distal most section with a portion of the distal most section extending through the bore.

35. The magnetically navigable catheter according to claim 24 wherein the portion of the distal most section extending through the bore has a reduced external diameter.

36. The magnetically navigable catheter according to claim 24 wherein the body is mounted in the lumen of the distal most section.

37. The catheter according to claim 24 wherein the catheter has at least one lateral opening therein, and wherein the body is distal to the lateral openings.

38. A method of navigating the distal end of a variable stiffness through branched blood vessel, the method comprising advancing the distal end of the catheter through the blood vessel; selectively allowing the distal end of the catheter to follow the branch having the greatest flow therein; and selectively applying a magnetic field

- 5 and/or gradient to a magnet body on the distal end of the catheter to move the distal end of the catheter to follow a branch other than the branch having the greatest flow therein.

39. The method according to claim 38 the step of selectively applying a magnetic field and/or gradient is performed with at least one moveable magnet.

40. The method according to claim 38 wherein the step of selectively applying a magnetic field and/or gradient is performed with at least one stationary magnet.

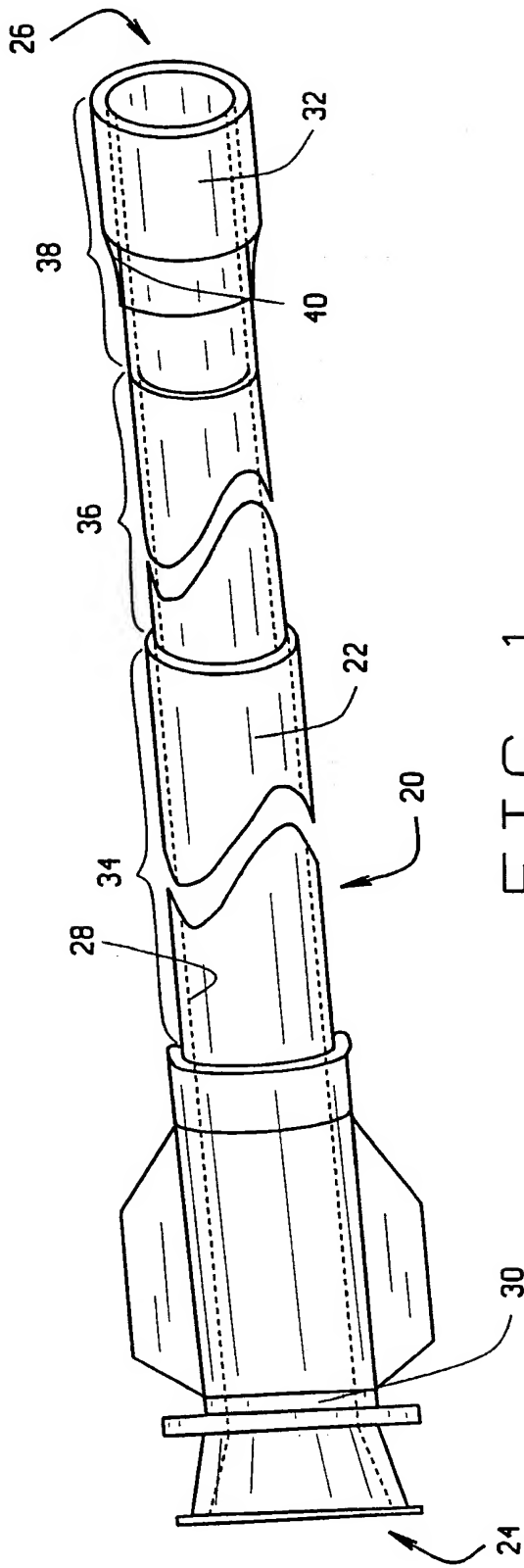


FIG. 1

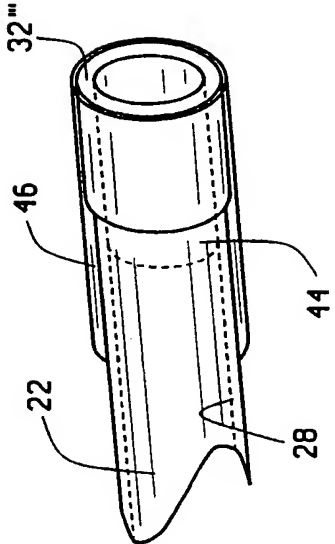


FIG. 2

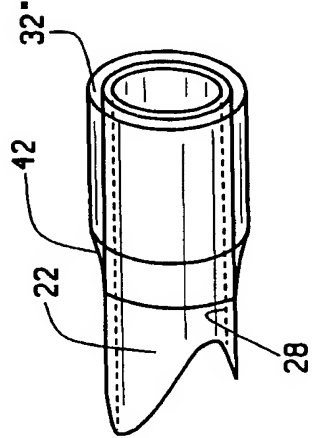


FIG. 3

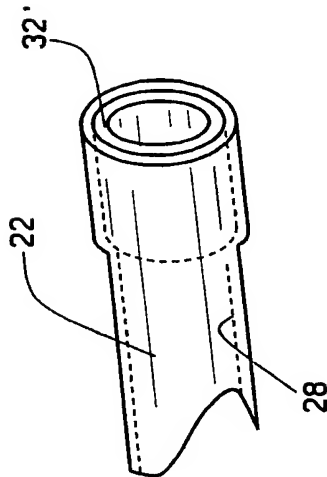


FIG. 4

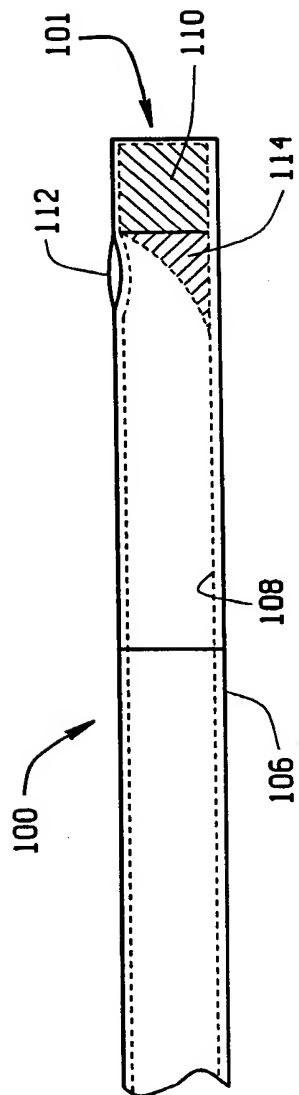


FIG. 5

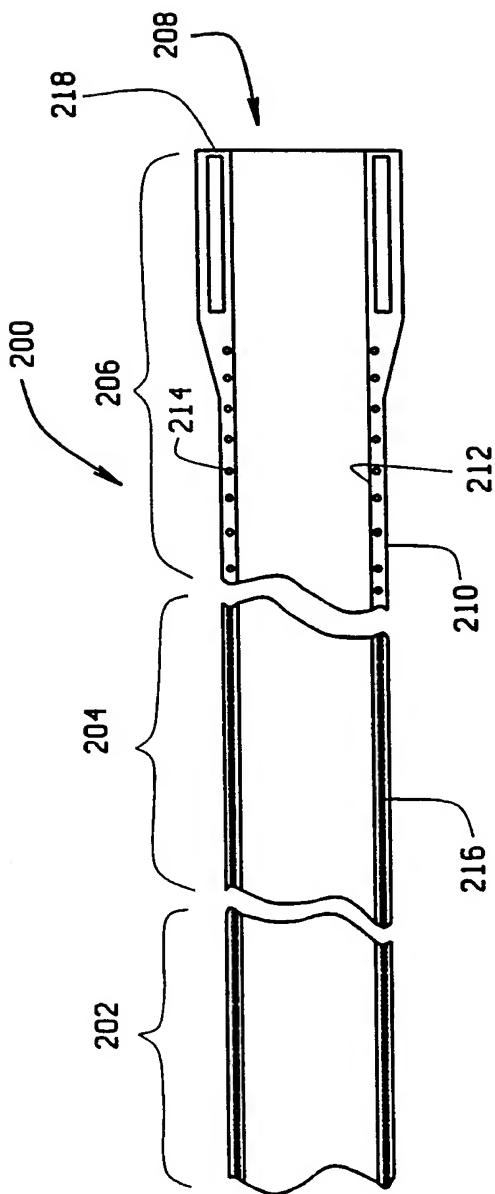


FIG. 6



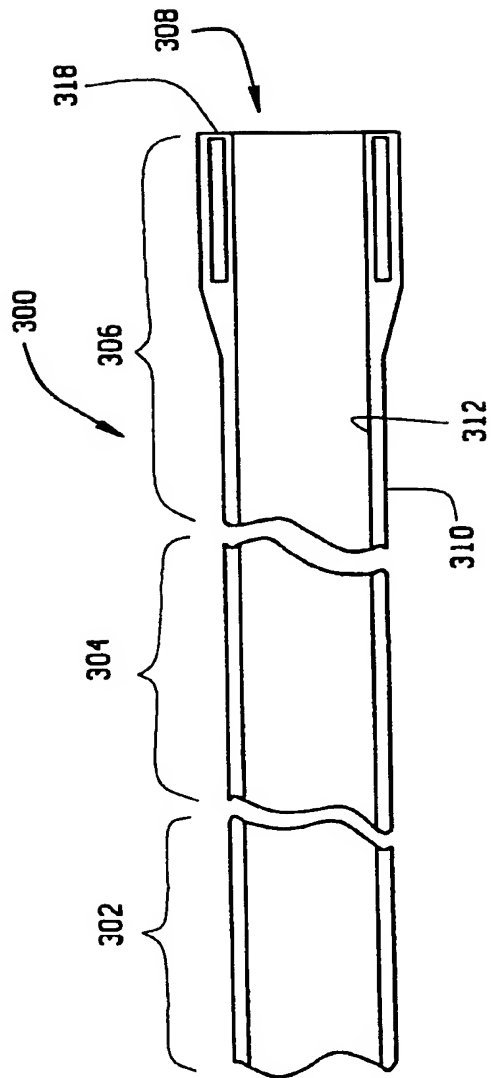


FIG. 7

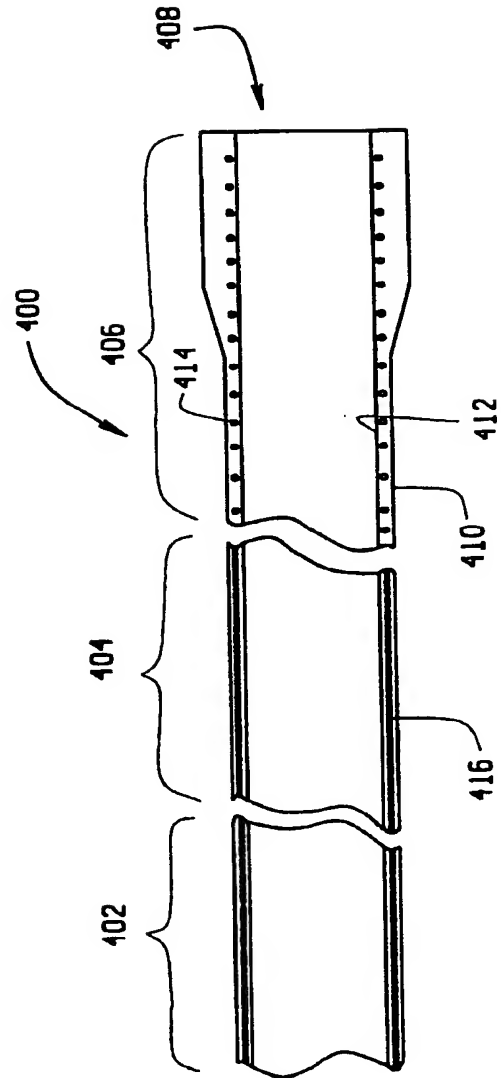
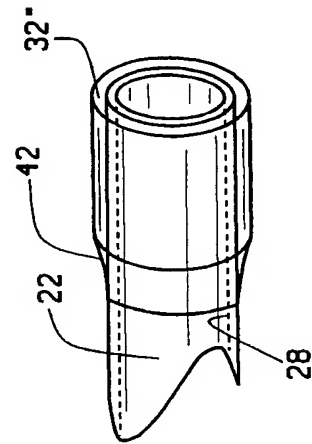
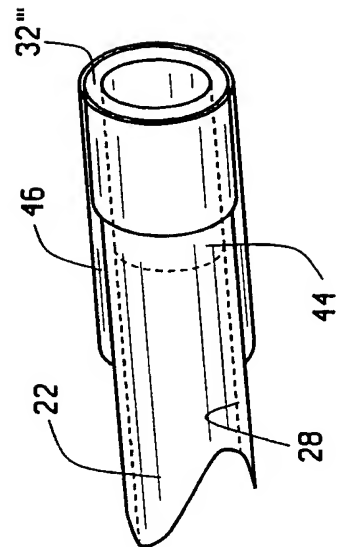
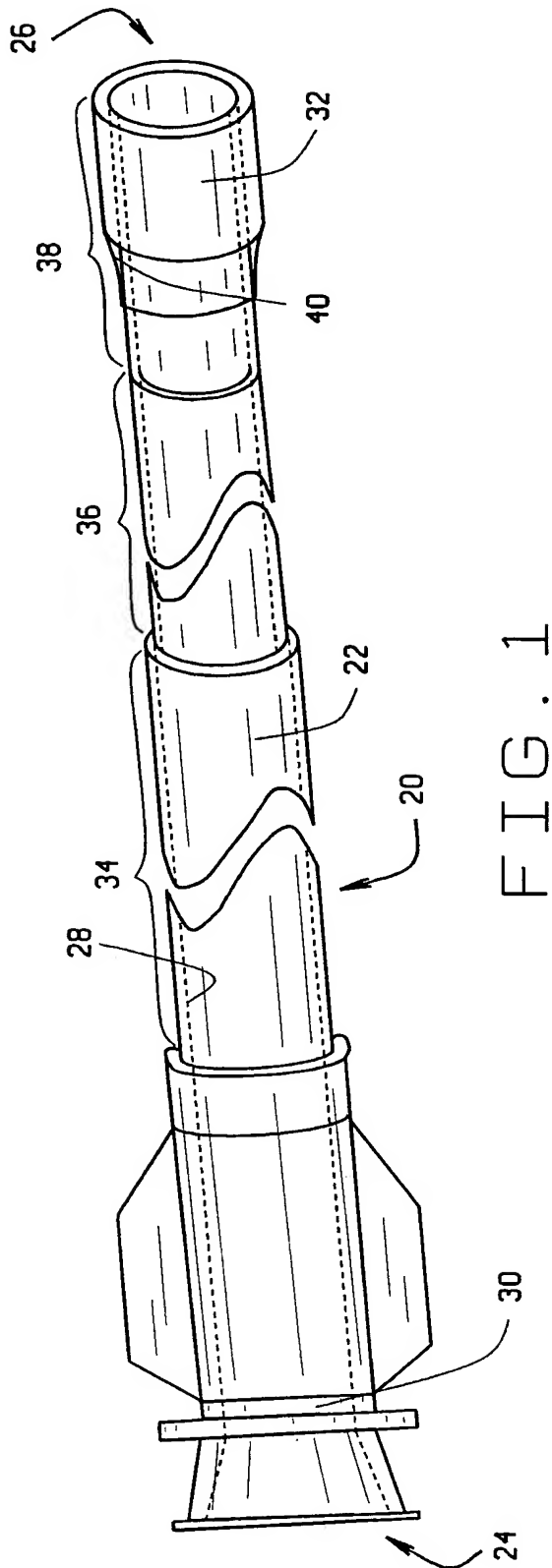


FIG. 8



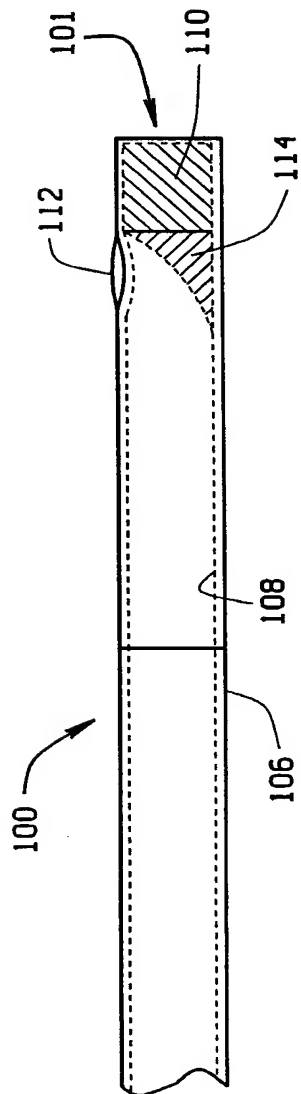


FIG. 5

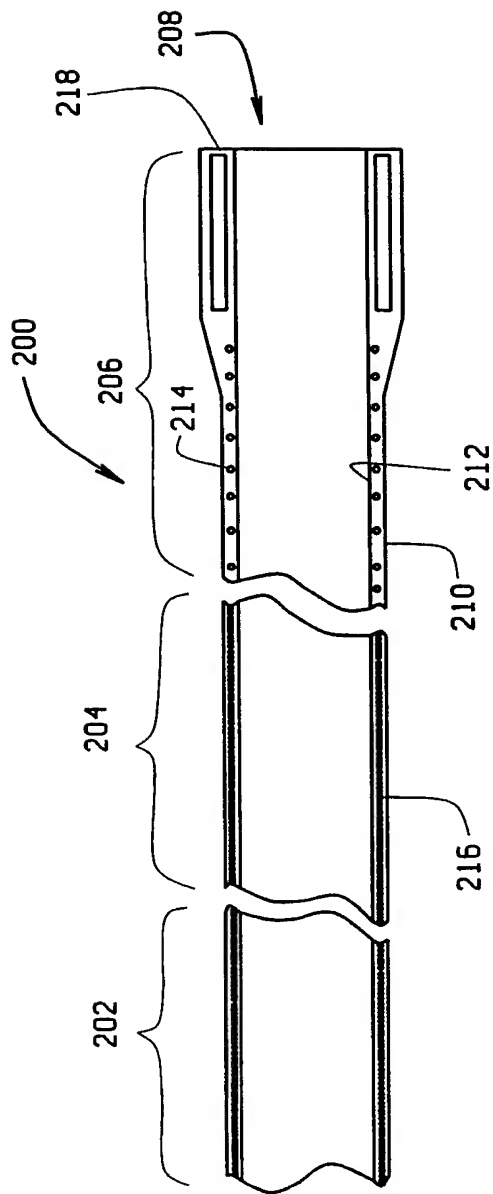
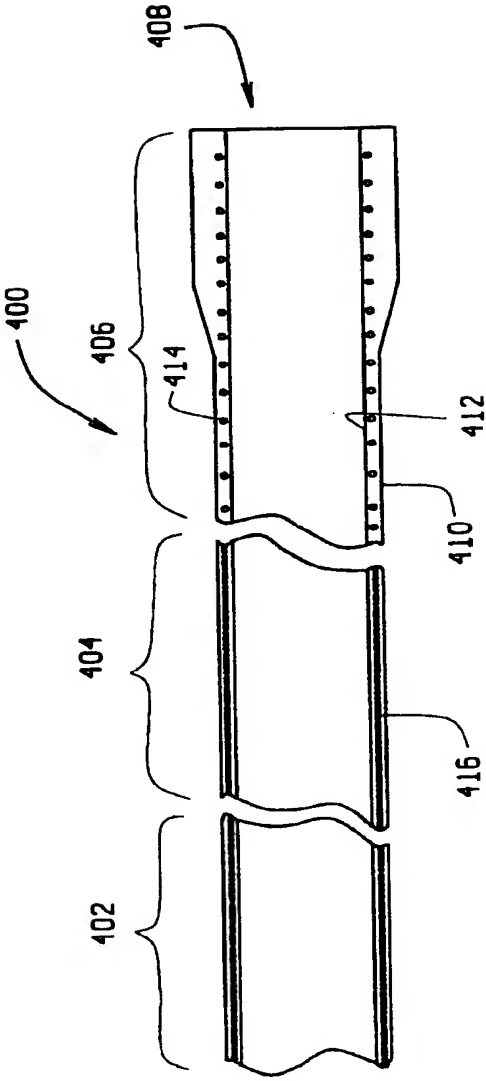
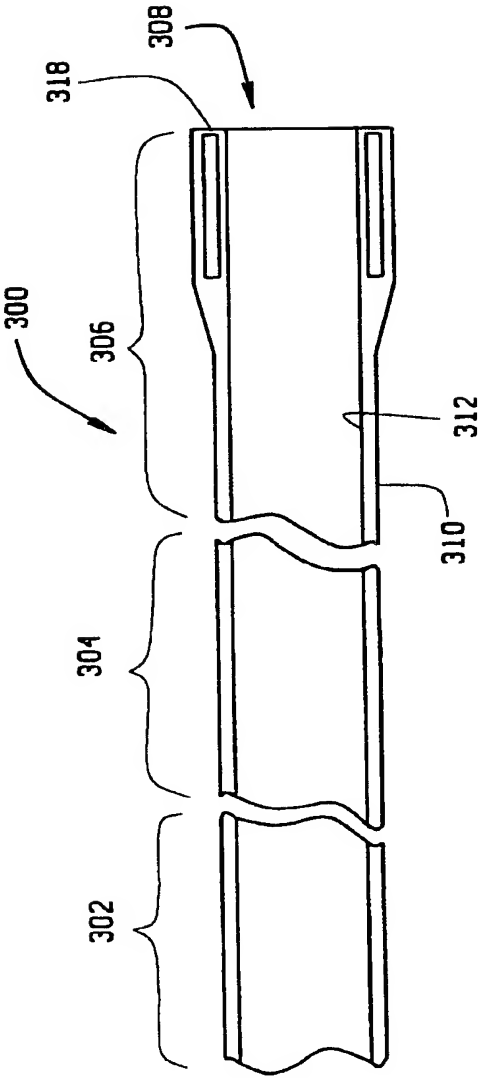


FIG. 6



# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US00/24809

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :A61M 25/00

US CL :604/528

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 604/523-530

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---	US 3,674,014 A (TILLANDER) 4 July 1972, entire document.	1, 8, 10, 12, 13 -----
Y		2-7, 9, 11, 14-40
X ---	US 4,249,536 A (VEGA) 10 February 1981, col. 5, lines 32-40, col. 8, line 55 to col. 9, line 29.	1, 8, 10, 11, 24, 35, 37 -----
Y		2-7, 9, 12-23, 25-34, 36, 38-40
A	US 5,542,938 A (AVELLANET et al) 6 August 1996, abstract.	1

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*&* document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search	Date of mailing of the international search report
27 NOVEMBER 2000	02 JAN 2001

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# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US00/24809

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	EP 0 422 689 A2 (FIDDLAN-GREEN) 17 APRIL 1991, col. 8, line 31 to col. 9, line 32, col. 10, lines 39-57.	1, 10, 24 ----- 2-9, 11-23, 25-40